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Middle Jurassic of north central Montana and adjacent areas of Canada

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MIDDLE JURASSIC OF NORTH CENTRAL MONTANA AND ADJACENT AREAS OF CANADA

by

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Fred S. Honkala
Chairman, Board of Examiners

Dean, Graduate School

Date

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ABSTRACT

Middle Jurassic sediments in north-central Montana and adjacent areas of Canada are subdivided using formational and member designations of Nordquist (1955). The Nesson formation is confined to the eastern and northern sector of study. It consists of three lithologic members which from bottom to top are the Poe evaporite member, Picard shale member and Kline carbonate member. The overlying Piper formation consists of three lithologic members which from bottom to top are the Tampico shale member, Firemoon limestone member and the Bowes sandstone and shale member.

Middle Jurassic isopachous and lithofacies maps are presented which imply a normal shelf to basin sedimentation with modifications by local environmental conditions. The sediments include a near shore sand and limestone facies that grades basinward to a carbonate and shale lithology. They imply deposition in warm shallow waters with relatively low energy levels except during Bowes deposition.

Sandstones in the Bowes member of the Piper formation indicate local uplift in western Montana. Cross-bedded sands, oolites, and bioclastic limestone fragments suggest strong depositional currents. The principal cements are calcium carbonate and silica.

Middle Jurassic limestones are classified as chemical

(basal part of the Firemoon limestone member), biochemical (Nesson formation and upper part of the Firemoon limestone member), and bioclastic (Bowes sandstone and shale member). Metasomatic replacement of Ca ions by Mg ions in limestone is postulated to account for most of the dolomite. Red beds and associated anhydrite are believed to indicate a restricted marine environment accompanied by subareal conditions.

The reason or reasons for the lack of large petroleum reservoirs is not known. Possible explanations are flushing by subsequent fresh water migration and partial loss of porosity and permeability because of cementation and recrystallization.

INTRODUCTION

Purpose of Investigation

This report is a detailed study of Middle Jurassic strata and related petroleum possibilities in north-central Montana and adjacent areas of Canada. Previous studies have emphasized the Williston Basin to the east. It is felt a detailed sedimentation study of the area will add to the overall Middle Jurassic information and is warranted by the petroleum possibilities in this region. The sedimentation pattern is illustrated by a series of composite isopachous-lithofacies maps.

Two secondary and related purposes of this study are: (1) a review of conflicting nomenclature and (2) correlation of stratigraphic equivalents.

Area of Investigation

The area of investigation (fig. 1) includes eastern Toole, northern Chouteau, Liberty, Hill, Blaine and Phillips Counties and extends 36 miles north of the International Boundary into Alberta and Saskatchewan. The Montana principal meridian is the western boundary of study area which extends eastward through R. 34E. The base of T. 25N (approximately the 48th parallel) is the southern boundary.

Method of Investigation

Cores and cuttings of fifty-eight subsurface sections were examined and described. Lithology was recorded in five-foot intervals. Physical properties such as color, crystal size, degree of rounding and sorting, texture, type of cementation, fossils and minor accessary minerals were recorded. Lithologic distinctions between sandstone and limestone were made by dissolving small sample fragments in dilute hydrochloric acid and estimating the percentage of remaining sand. Sample depths were adjusted to conform with electric log information and recorded on graphic log strips. In addition, 143 electric logs from other wells in the region were used to determine thickness variations of the stratigraphic units.

The relative amounts of carbonate, sandstone and shale were determined for each well or designated interval and applied to a lithologic triangle as developed by Krumbein (1951, p. 273-275) and discussed by Pettijohn (1957, p. 187-190). The lithologic components of primary interest, namely carbonate and quartz, were placed at the base of the triangle to obtain a direct ratio. The two ratios obtained were

$$\frac{\text{Sandstone}}{\text{Carbonate}} \qquad \frac{\text{Sandstone Carbonate}}{\text{Shale}}$$

The lithofacies maps were constructed by contouring the individual ratios plotted at each well location.

Previous Investigations

Weed (1892, p. 309) observed Jurassic sediments in the Sweetgrass Arch vicinity and Peale (1893, Pl. 1) applied the name Ellis formation to similar age sediments in the vicinity of Bozeman, Montana. The Piper formation (Imlay, et al, 1948) is equivalent to the lower member of the Ellis formation as applied by Weed (1899, p. 2) to Jurassic sediments in central Montana.

Cobban (1945) raised the Ellis from formational to group status and subdivided it into the Sawtooth, Rierdon and Swift formations. Imlay, et al, (1948) defined the Piper formation as including gypsum beds, red beds, and associated normal marine beds of Middle Jurassic age underlying the Rierdon formation in central and eastern Montana (east of the Sweetgrass Arch-Big Belt uplift, fig. 2).

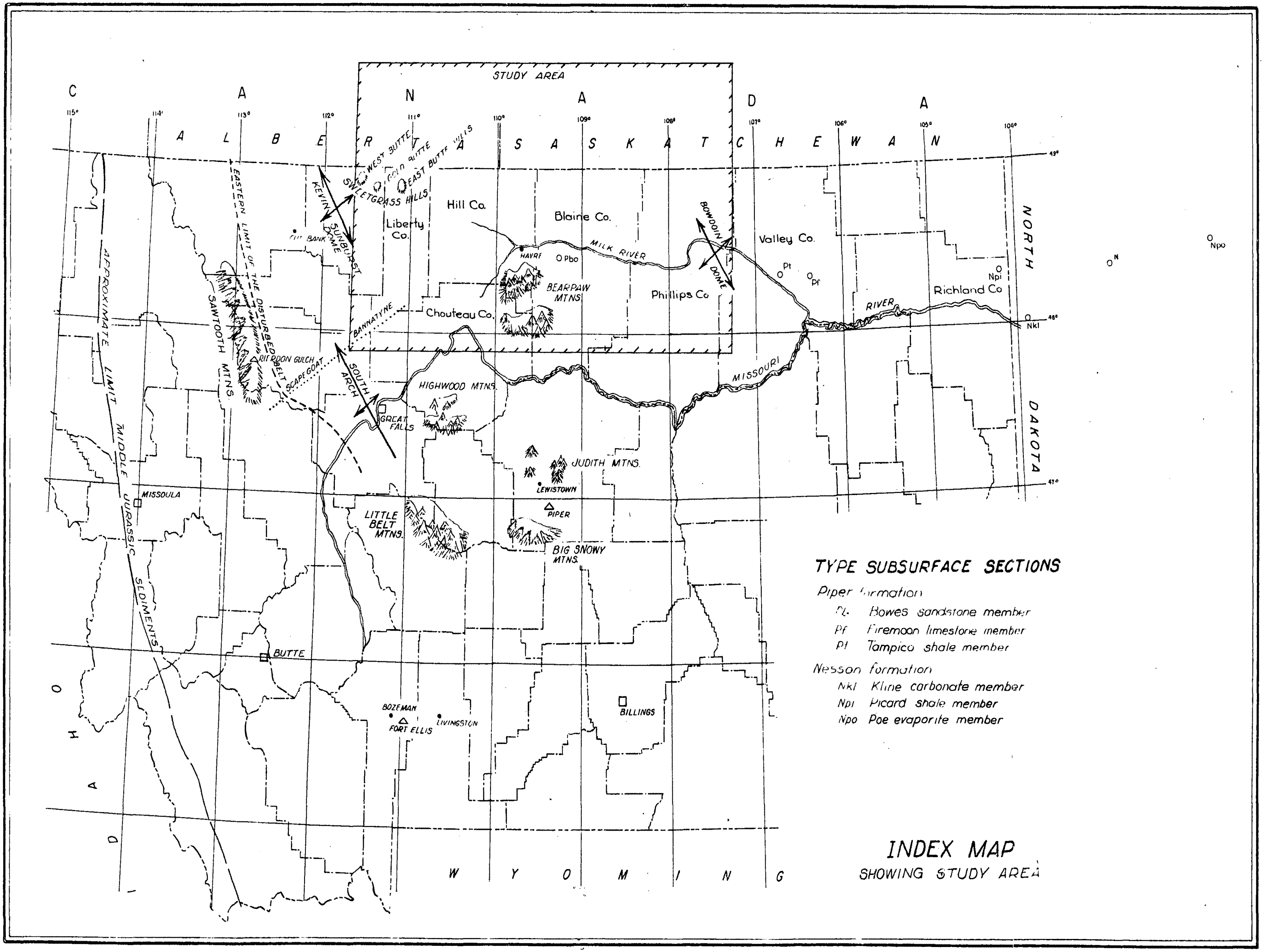
Studies by Schmitt (1953) and Towse (1954) established the presence of these sediments in the Williston Basin. In Saskatchewan, Milner and Thomas (1954) subdivided the Middle Jurassic into the Watrous, Gravelbourg and Shaunavon formations.

Nordquist (1955) and Francis (1957) made similar and more workable subdivisions and correlations of the Middle Jurassic in the Williston Basin, which will be discussed in more detail under terminology.

Peterson (1957) classified the Middle Jurassic sediments in ascending order as the Piper "A" unit (lower red beds and anhydrite), the Piper "B" unit (normal marine sequence), and the Piper "C" unit (overlying red beds).

Acknowledgments

The writer wishes to express his appreciation for the assistance received in making this study and report. The base maps were supplied by Sinclair Oil and Gas Company. C. P. Abrassart, Sinclair district geologist, suggested the project and gave helpful advice as the study progressed. American Stratigraphic Company in Billings furnished well samples, thin sections and other facilities for the study. C. A. Balster of this company and his staff gave encouragement and helpful suggestions. Central Canadian Stratigraphic Ltd., Regina, Saskatchewan, also provided samples and facilities. Phillips Petroleum Company supplied the microscope used for sample examination. Dr. F. S. Honkala and Dr. R. W. Fields of Montana State University and C. A. Balster reviewed the manuscript and made helpful comments and suggestions.



INDEX MAP
SHOWING STUDY AREA

PALEOTECTONIC HISTORY

During Middle Jurassic north-central Montana was a shelf area situated between two negative trends, the north-south trending Alberta trough on the west and the northwest trending Williston Basin on the east (see fig. 2). The Sweetgrass trough was a minor east-west negative trend in the vicinity of the International Boundary in eastern Toole and Liberty Counties.

The term, Belt Island, was proposed by Imlay, et al (1948), for the low irregular shaped positive area including the southern part of the Sweetgrass Arch (south of the Marias River), the Big Belt, Little Belt and Big Snowy uplifts and extending eastward to the Little Rocky Mountains. Thus, Belt Island was located near the southern boundary of this report area. In addition to providing a partial source of the Middle Jurassic clastics, Belt Island influenced marine currents, temperatures, salinities and faunal distribution (Imlay, et al, 1948) (Peterson, 1957, p. 403). During Middle Jurassic local relief was present in north-central Montana, but it appears to have been of less magnitude than in Saskatchewan and Manitoba (Francis, 1957, p. 370).

Figure 2 represents the generalized paleotectonic pattern in Montana during Middle Jurassic. The paleogeology in the study area at the beginning of Middle Jurassic is superimposed on figure 2. Middle Jurassic sediments in north-central Montana rest unconformably on the Mission Canyon limestone of Mississippian age except in the extreme eastern sector where they overlie the Spearfish formation of Triassic? age.

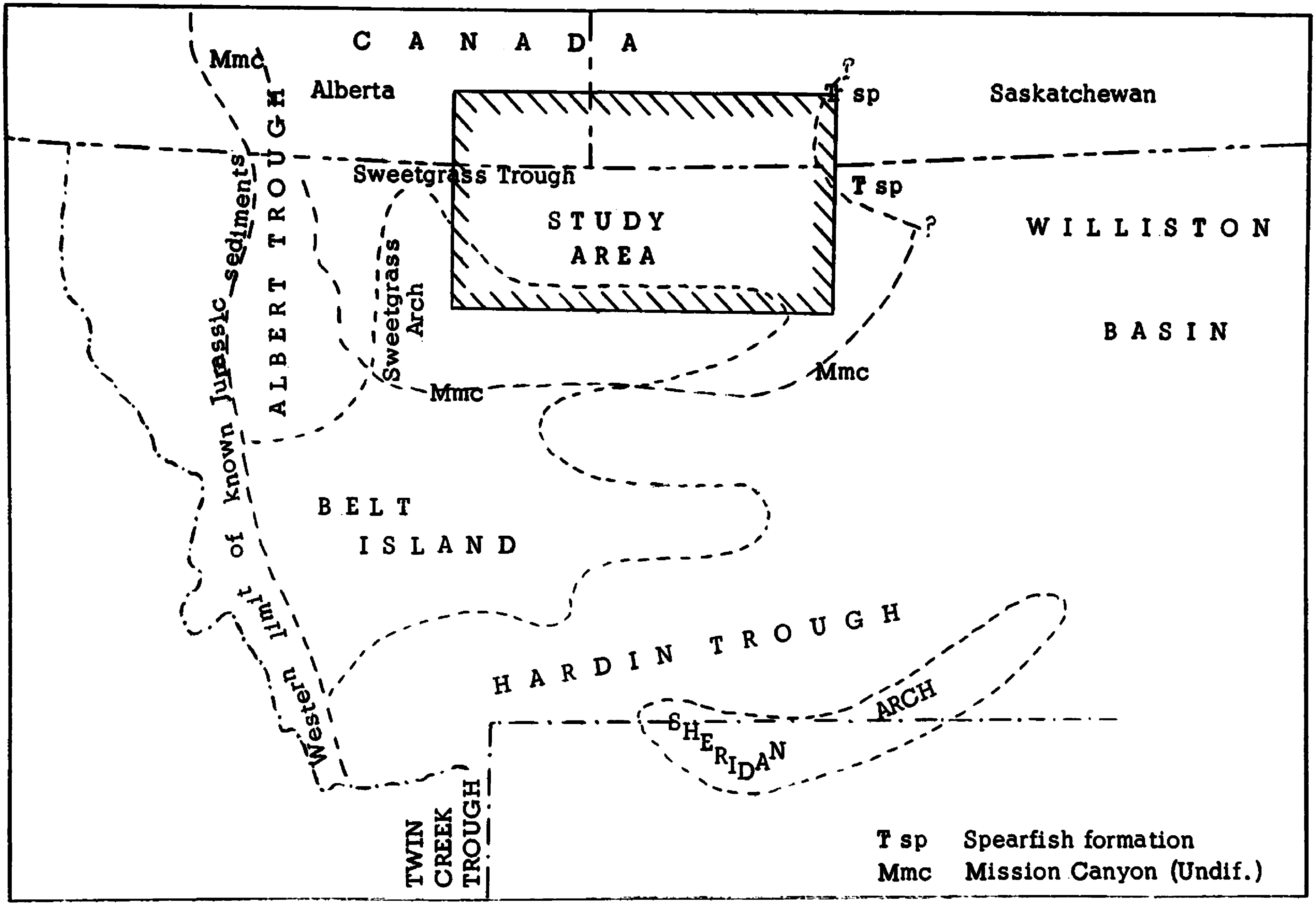


Figure 2. Generalized Jurassic Paleotectonic map after Peterson (1957, p. 403)
Paleogeology in part after Imlay (1957, Plate 2)

MIDDLE JURASSIC NOMENCLATURE

Middle Jurassic nomenclature has developed over a period of years as various formational and member designations were applied to Montana and adjacent areas by different stratigraphers. Because of facies changes, large areal distances and lack of subsurface control, it is quite understandable that nomenclature conflicts have developed. The writer as a result of this work has concluded that the following formation terminology as advocated by Nordquist (1955) is the most appropriate for Middle Jurassic sediments in the study area.

Nesson formation

The Nesson formation (Nordquist, 1955) is a Middle Jurassic carbonate and evaporite sequence underlying the Piper formation in the eastern part of the study area and in the Williston Basin. It is subdivided into three members which from bottom to top are the Poe evaporite member, Picard shale member and Kline carbonate member. The Nesson formation is confined to the subsurface in north-central Montana and the Williston Basin. Nordquist designated a typical subsurface section as being in the 5730-5990 foot interval in the Amerada No. 1 Iverson well, Williams County, North Dakota. In the study area its thickness varies from about 150 feet in the northeastern sector to a featheredge on the flanks of Belt Island.

Francis (1957) designated this interval as the Gypsum Springs formation (Love, 1939), correlating with exposures in the Black Hills (Imlay, 1947) which can be traced northward into the Williston Basin subsurface. This terminology may cause confusion as Imlay (1956, p. 584-85) suggests the Gypsum Springs formation in north-central Wyoming and the Piper formation in southern Montana are time equivalents.

Piper formation

The Piper formation as defined by Imlay, et al, (1948) includes all Middle Jurassic red beds, gypsum and associated normal marine beds underlying the Rierdon formation. The type section one mile south of Piper, Montana, is 93 feet thick and consists of a basal gypsum unit and overlying siltstone, shale and limestone.

The Piper formation as used in this report is restricted to Middle Jurassic sediments lying between the Nesson and Rierdon formations. It is subdivided into three members (Nordquist, 1955) which from bottom to top are the Tampico shale member, Firemoon limestone member, and Bowes sandstone and shale member. The Piper formation attains a maximum thickness of about 300 feet in the northeastern sector of the study area and thins to a featheredge in the vicinity of Belt Island.

Sawtooth formation

The Sawtooth formation was named and described by Cobban

(1945) at Rierdon Gulch, Pondera County, Montana. There it includes a lower fine-grained sandstone, a medial dark gray-shale and an upper siltstone member. The eastern boundary of the Sawtooth formation is considered to be in the Sweetgrass Hills vicinity, where it intertongues with the Piper formation.

Table 3 illustrates the terminology applied to Middle Jurassic sediments by stratigraphers in Montana and adjacent areas. The writer accepts responsibility for any deviation from the original interpretations such as the slight modification in correlations and suggested hiatuses.

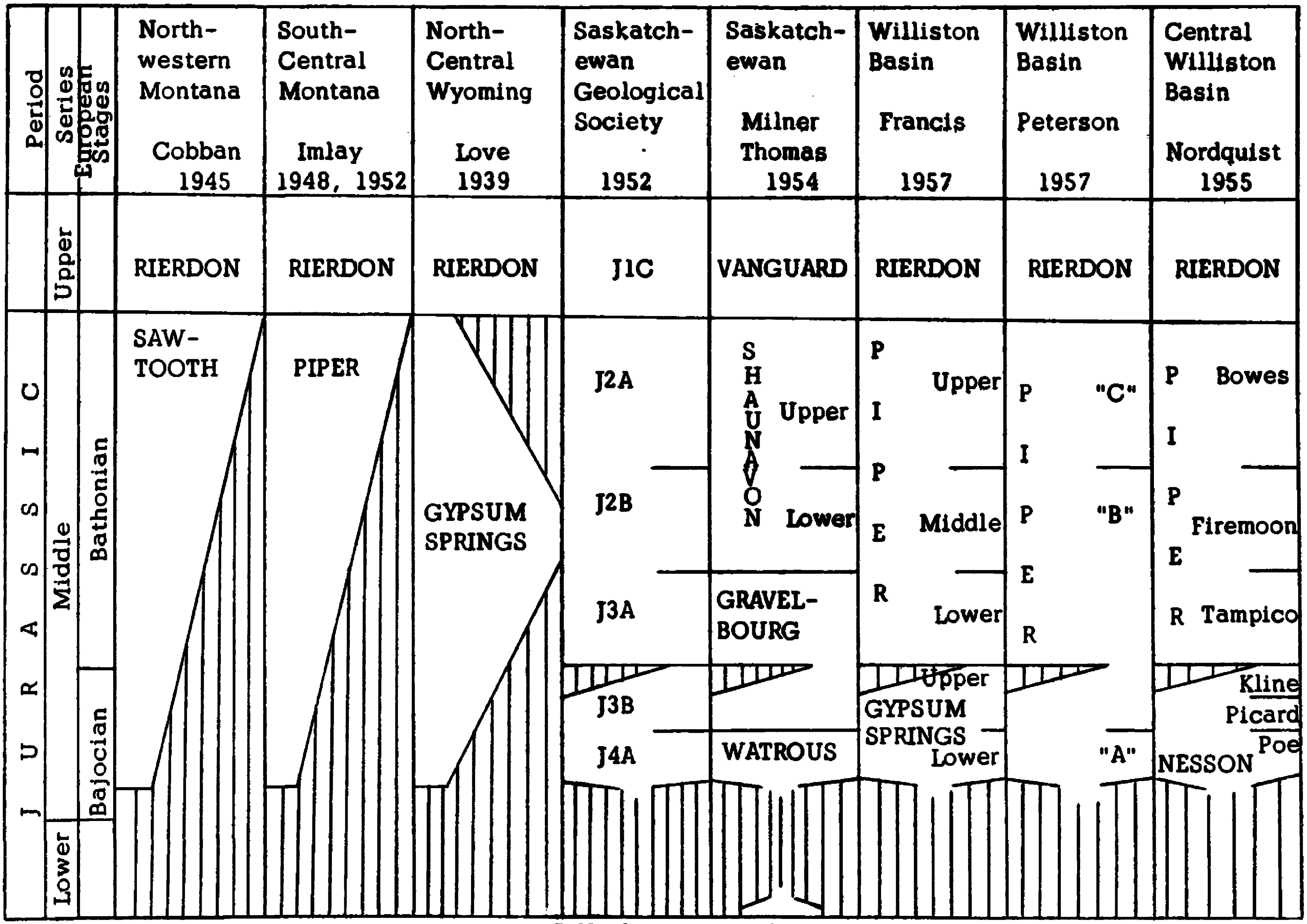


Table 3. TIME-ROCK CORRELATION OF MIDDLE JURASSIC FORMATIONS IN MONTANA AND ADJACENT AREAS

STRATIGRAPHY

Nesson formation

The Nesson formation (Nordquist, 1955, p. 104) includes carbonate, evaporite and shale strata which are stratigraphically lower than the sediments at the type Piper section. It consists of three members which from bottom to top are the Poe evaporite member, the Picard shale member and the Kline carbonate member. The Nesson formation is well developed in the Nesson anticline vicinity of North Dakota and derives its name from that structure. The typical subsurface section occurs in the 5730-5990 foot interval in the Amerada No. 1 Clarence Iverson well, Williams County, North Dakota.

The three-fold lithologic sequence of the Nesson formation is locally well developed in Phillips County and adjacent parts of Saskatchewan. The formation is approximately 150 feet thick in the northeastern sector of the study area. It thins to the south and west and wedges out relatively low on Belt Island and the eastern edge of the Alberta shelf. The thickness and distribution of the sediments are illustrated in Plate 2.

Poe evaporite and Picard shale members

The Poe evaporite and Picard shale members are herein discussed jointly because the increased shale content of the Poe member hinders subsurface correlation and differentiation of the Picard shale member.

The type subsurface section of the Poe evaporite member (Nordquist, 1955, p. 104) is the 6947-7065 foot interval in the Phillips-Skelly-Gulf Hoehn No. 1 (Poe unit) well, McKenzie County, North Dakota. Throughout the Williston Basin the Poe member is primarily an anhydrite with varying amounts of interbedded shale and dolomite.

The type subsurface section of the Picard shale member (Nordquist, 1955, p. 105) occurs in the 6610-6650 foot interval in the Deep Rock Oil Corporation Picard No. 1 well, Roosevelt County, Montana. This thin persistent shale unit is present in North Dakota and eastern Montana.

In the study area the Poe evaporite member rests unconformably on the Mission Canyon limestone of Mississipian age except in the easternmost part of the area where it rests on the Spearfish formation[1] of Triassic? age. The Spearfish formation is characterized by red-orange siltstone to very fine-grained sandstone as compared to the red-brown shale of the Poe evaporite member. The contact between the Poe evaporite and Picard shale members appears conformable as does the contact between the Picard shale and the overlying Kline carbonate

1. The Spearfish formation, as used in this report, is the stratigraphic equivalent of the Jura-Triassic beds (Francis, 1957) and the Saude formation (Zieglar, 1956).

member. The maximum thickness of the Poe evaporite and Picard shale member is approximately 100 feet. Both members thin to the west, pinching out relatively low on Belt Island.

The Poe evaporite and Picard shale members have a heterogeneous lithology. The red-brown and gray-green shale is slightly dolomitic and locally exhibits a mottled red and green appearance. Thin beds of anhydrite and dolomite are commonly interbedded with the shale. Locally, massive anhydrite sections are present. The anhydrite is usually white and commonly exhibits a microsucrosic texture. Plates 1, 2, and 5 illustrate the variations in lithology.

The Poe evaporite and Picard shale members are essentially the stratigraphic equivalent of the evaporite member in the Watrous formation (Milner and Thomas, 1954), the lower member of the Gypsum Springs formation (Francis, 1957) and the Piper "A" unit (Peterson, 1957).

Kline carbonate member

The type subsurface section of the Kline carbonate member (Nordquist,1955, p. 105) is the 4386-4533 foot interval in the Price Drilling Company Kline No. 1 well, Ward County, North Dakota. The unit is primarily a carbonate with minor amounts of interbedded shale and anhydrite.

In the study area the Kline carbonate member appears to be conformable with the underlying Picard shale member or it rests unconformably on the Mission Canyon limestone. The latter contact is usually well defined. However, in parts of Hill and Blaine Counties and northward in Saskatchewan the Mission Canyon is locally dolomitized and is difficult to distinguish from the Kline carbonate member. Differentiation between the Jurassic and the Mississippian dolomite is based on the dense argillaceous nature of the Kline member as compared with the coarser textured, non-argillaceous Mission Canyon dolomite.

Near its depositional edge the contact between the Kline carbonate member and the overlying Tampico shale member of the Piper formation is sharp. Basinward the contact becomes gradational and appears to be conformable. The member varies in thickness from approximately 100 feet to a featheredge in the vicinity of Belt Island.

The Kline carbonate member is a cream to light gray, dense, argillaceous dolomite interbedded with thin stringers of shale and anhydrite. The dolomite grades northeastward to a light gray, dense, argillaceous limestone. Quartz rosettes and blue translucent chert are common near its depositional edge. Lithologic variations are illustrated by plates 1, 2, 3 and 5.

The Kline carbonate member is the stratigraphic equivalent of the lower member of the Gravelbourg formation (Milner and Thomas, 1954), the upper member of the Gypsum Springs formation (Francis, 1957), and the lower member of the Piper "B" unit (Peterson, 1957).

The writer is not aware of any diagnostic fossils in the Poe and Picard members. Their age is inferred by stratigraphic position and their apparent conformable relationship with overlying beds in the northern part of the Williston Basin. Milner and Thomas (1954, p. 259) report pelecypods and algal growths in the Kline equivalent. Loranger (1955, p. 38, 40) reports smooth shelled ostracods in this interval suggesting a Bathonian age.

Piper Formation

In north-central Montana the Piper formation includes three members as proposed by Nordquist (1955) which from bottom to top are: the Tampico shale member, the Firemoon limestone member and the Bowes sandstone and shale member. The maximum thickness of the Piper formation is approximately 300 feet in the eastern sector of study It thins westward to about 10 feet in the Kevin-Sunburst dome and pinches out on the northern flank of Belt Island. The upper members progressively overlap underlying units. The lithology and thickness of the Piper formation are illustrated in Map 3.

Tampico shale member

The type subsurface section of the Tampico shale member (Nordquist, 1955, p. 101) is in the 3858-3944 foot interval in the Gulf

Oil Corporation No. 1 Cornwell well, Valley County, Montana. The member receives its name from the town of Tampico, Montana, which is five miles southwest of the well

In the study area the Tampico shale member rests unconformably on the Mission Canyon limestone where the Nesson formation is absent due to either non-deposition or subsequent erosion. The gradational contact with the overlying Firemoon limestone member is interpreted as conformable. Its thickness is variable ranging from approximately 90 feet in the vicinity of Bowes field (fig. 4) to a featheredge on the northern flank of Belt Island. Westward it pinches out on the flank of the Sweetgrass Arch in central Liberty County.

In Liberty, Hill, and Blaine Counties and in Saskatchewan the Tampico shale is a green-gray, fissile slightly calcareous to marly shale with occasional thin, gray dense interbedded limestone. A brecciated sandy limestone or fine to very fine-grained basal sandstone is locally present when the unit rests directly on the Mission Canyon limestone. In Liberty and western Hill Counties thin varicolored beds of red-brown shale are interbedded with the gray-green shale.

In parts of Phillips County and northward into Saskatchewan, the Tampico interval is occupied by a light gray, fine-grained sandstone. In eastern Phillips County the Tampico shale grades laterally eastward to a red-brown, slightly silty, non-calcareous shale.

Interbedded gray-green and red-brown shale are present in several wells in this vicinity. Lithologic and thickness variations are illustrated by Plates 1-5.

The Tampico shale member is the stratigraphic equivalent of the upper Gravelbourg formation (Milner and Thomas, 1954), the lower member of the Piper formation (Francis 1957), and the partial equivalent of the Piper "B" unit (Peterson, 1957).

Firemoon limestone member

The type subsurface section of the Firemoon limestone member (Nordquist, 1955, p. 101) is the 4618-4687 foot interval in the Murphy Corporation No. 1 Firemoon well, Valley County, Montana.

The Firemoon limestone member, commonly referred to as the "Piper limestone," is gradational with the underlying Tampico shale member. In the southern sector of study near its depositional edge the Firemoon overlaps the Tampico member and rests unconformably on the Mission Canyon limestone of Mississippian age (see plates 1, 3, 4, 5). The upper contact with the Bowes member appears gradational and is considered conformable.

Usually the dense argillaceous limestone of the Firemoon member is easily distinguished from the coarse crystalline Mission Canyon limestone, but in the western sector of the study differentiation is more difficult as it is occasionally dolomitic and cherty.

The thickness of the Firemoon varies from 90 feet in Saskatchewan to a featheredge on the northern flank of Belt Island. Its average thickness in Hill, Blaine, and Phillips Counties is approximately 60 feet. The member is the best stratigraphic and electric log marker in the area.

The lower part of the Firemoon member is commonly a dark-brown, dense, non-fossiliferous limestone with sublithographic texture. The remainder of the unit is usually a buff to light tan microcrystalline argillaceous limestone which becomes slightly oolitic near the top. Thin beds of gray-green shale are common near the base and top. Algal impressions and thin beds of fragmental limestone are occasionally present. Locally, near its depositional edge in western Liberty County the Firemoon member becomes sandy and extremely argillaceous. Plates 1-5 illustrate variations in thickness and uniform lithology.

The Firemoon limestone member is the partial stratigraphic equivalent of the normal marine member of the Piper formation (Imlay, et al, 1948), the lower Shaunavon (Milner and Thomas, 1954), the middle member of the Piper formation (Francis, 1957) and the upper unit of the Piper "B" unit (Peterson, 1957).

<u>Bowes sandstone and shale member</u>

The type subsurface section of the Bowes sandstone and shale member (Nordquist, 1955, p. 102) is the 3360-4317 interval in the Northern Ordnance Guertzgen No. 1 well, Blaine County, Montana. The member is named from the Bowes field.

The Bowes sandstone and shale member is conformable with the underlying Firemoon limestone member in the study area. Its upper contact is placed on the highest sandstone bed below the Rierdon formation in eastern Toole, Liberty and Hill Counties. In Blaine and Phillips Counties and adjacent areas of southern Saskatchewan the contact between the Rierdon and the Bowes member is placed on a thin bioclastic limestone or sandy limestone. The Piper-Rierdon contact is considered essentially conformable though locally in the Sweetgrass Hills a slight disconformity may be present (Imlay, et al, 1948).

The thickness of the Bowes member is quite variable ranging from 80 feet to a featheredge on the northern flank of Belt Island. It thins westward to approximately 10 feet in the Kevin-Sunburst dome vicinity. The thickness and sedimentation pattern of the Bowes sandstone member is illustrated on Map 4.

The Bowes member is a heterogeneous unit containing sandstone, limestone and shale which exhibit both vertical and lateral gradational characteristics. In eastern Toole, Liberty and western Hill Counties the Bowes member grades from a fine-grained slightly calcareous sandstone to a sandy oolitic limestone. Pelecypod fragments are common and frequently form thin shelly beds. Traces of disseminated pyrite and glauconite are especially common near the base and top.

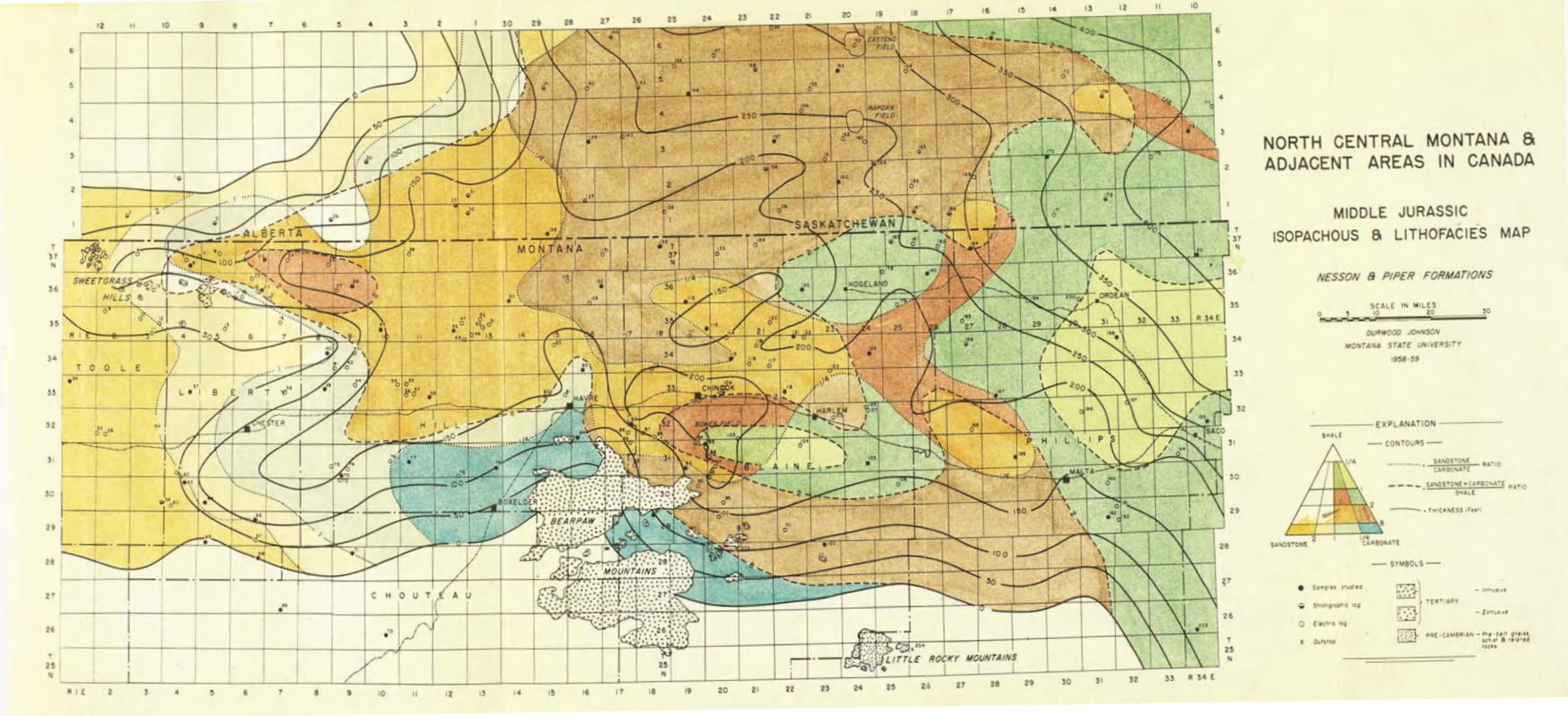
In eastern Hill and western Blaine Counties the Bowes member is primarily a cream-colored sandy oolitic limestone with thin beds of sandstone and shale. In parts of Blaine County and northward in southwestern Saskatchewan it is a sandy dolomite. Gray-green, slightly calcareous shale is the dominant lithology in eastern Blaine and Phillips Counties and southern Saskatchewan. The gray-green shale grades laterally to red-brown shale in eastern Phillips County, which is characteristic of the Bowes member throughout much of the Williston Basin. Plates 1-5 illustrate the variable thickness of the sands and lateral gradation to red beds.

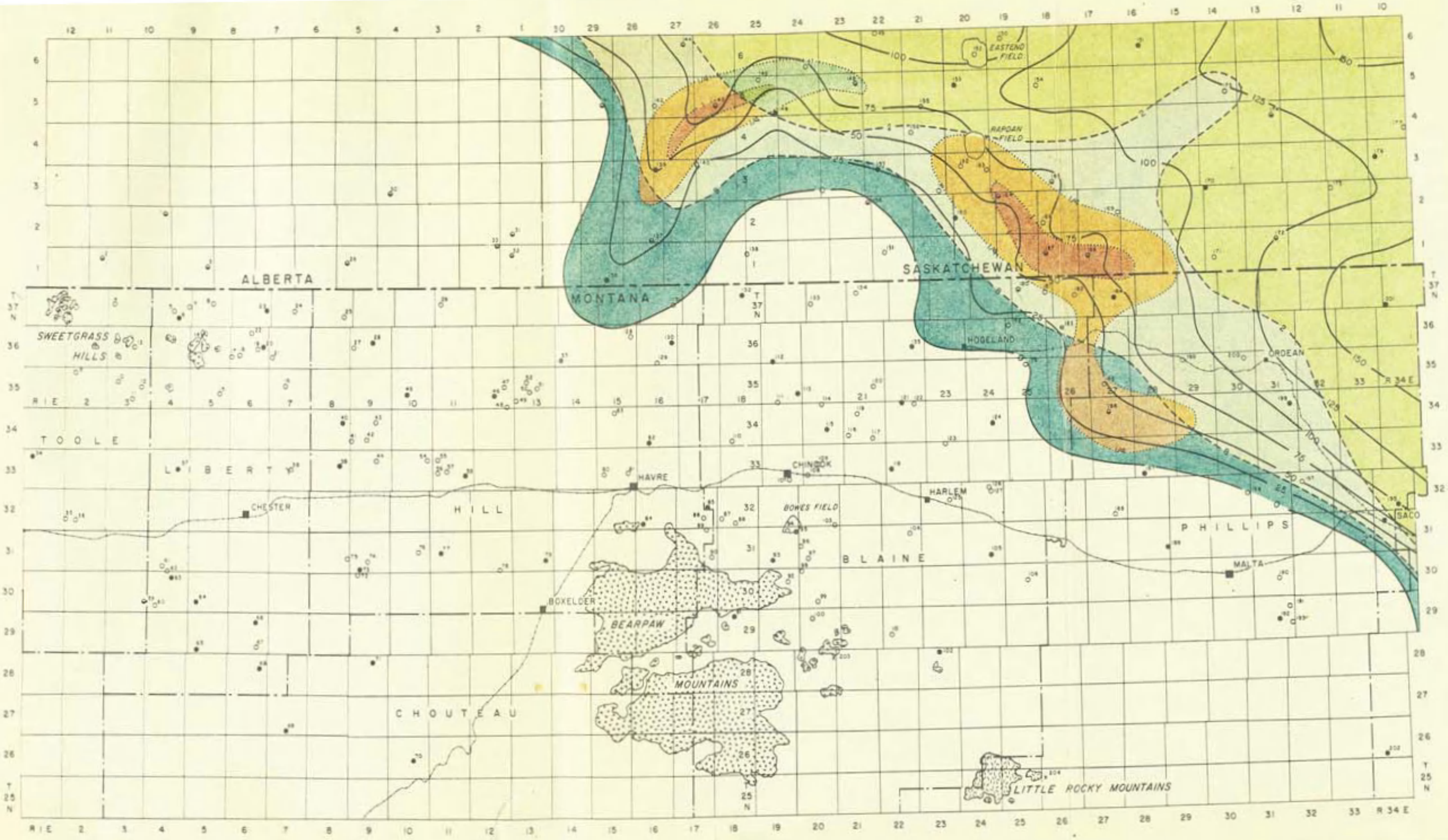
The Bowes member is the stratigraphic equivalent of the upper red bed member of the Piper formation (Imlay, et al, 1948), (Francis, 1957), the upper Shaunavon (Milner and Thomas, 1954) and the Piper "C" unit (Peterson, 1957).

The Piper formation contains an abundant fossil assemblage of pelecypods, brachiopods, coralline algae, Foraminifera, ostracods, charophytes, belemnites, echinoids, gastropods and radiolarians. Fresh water ostracods (Alpha, 1958, p. 20) in the Tampico member in Saskatchewan suggest a fresh water environment for at least a part of this interval. For a more detailed paleontological discussion the reader is referred to articles by Imlay (1948), (1956), Milner and Thomas (1954) and Loranger (1955).

Most of the species described by Loranger (1955) are present throughout the Piper interval. She describes the following species as characteristic of the different members of the Piper formation in Saskatchewan: *Citharina latissima* and *Guttulina pera* (Tampico shale member); *Procytheridea exempla* fauna described by Peterson (1954) (Firemoon limestone member); and *Nocanolella parryi* (Bowes sandstone and shale member).

The presence of numerous long range species offer little assistance in establishing exact age and suggests similar environmental conditions to those during Bathonian and Lower Callovian.


NORTH CENTRAL MONTANA & ADJACENT AREAS IN CANADA
MIDDLE JURASSIC ISOPACHOUS & LITHOFACIES MAP
NESSON & PIPER FORMATIONS
SCALE IN MILES
0 5 10 20 30
DURWOOD JOHNSON
MONTANA STATE UNIVERSITY
1958-59
EXPLANATION
SHALE
SANDSTONE
CARBONATE
CONTOURS
SANDSTONE / CARBONATE RATIO
SANDSTONE + CARBONATE / SHALE RATIO
THICKNESS (Feet)
SYMBOLS
Samples studied
Strатigraphic log
Electric log
Outcrop
TERTIARY
Intrusive
Extrusive
PRE-CAMBRIAN
ALBERTA
SASKATCHEWAN
MONTANA
SWEETGRASS HILLS
TOOLE
LIBERTY
HILL
CHOUTEAU
BLAINE
PHILLIPS
CHESTER
HAVRE
BOXELDER
CHINOOK
HARLEM
HOGELAND
ORDEAN
MALTA
SACO
EASTEND FIELD
RAPDAN FIELD
BOWES FIELD
BEARPAW MOUNTAINS
LITTLE ROCKY MOUNTAINS



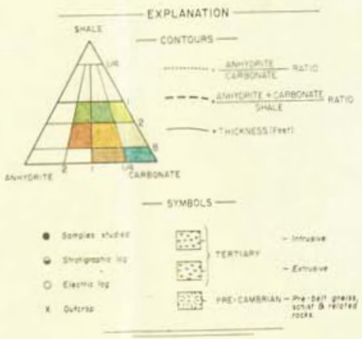
NORTH CENTRAL MONTANA & ADJACENT AREAS IN CANADA

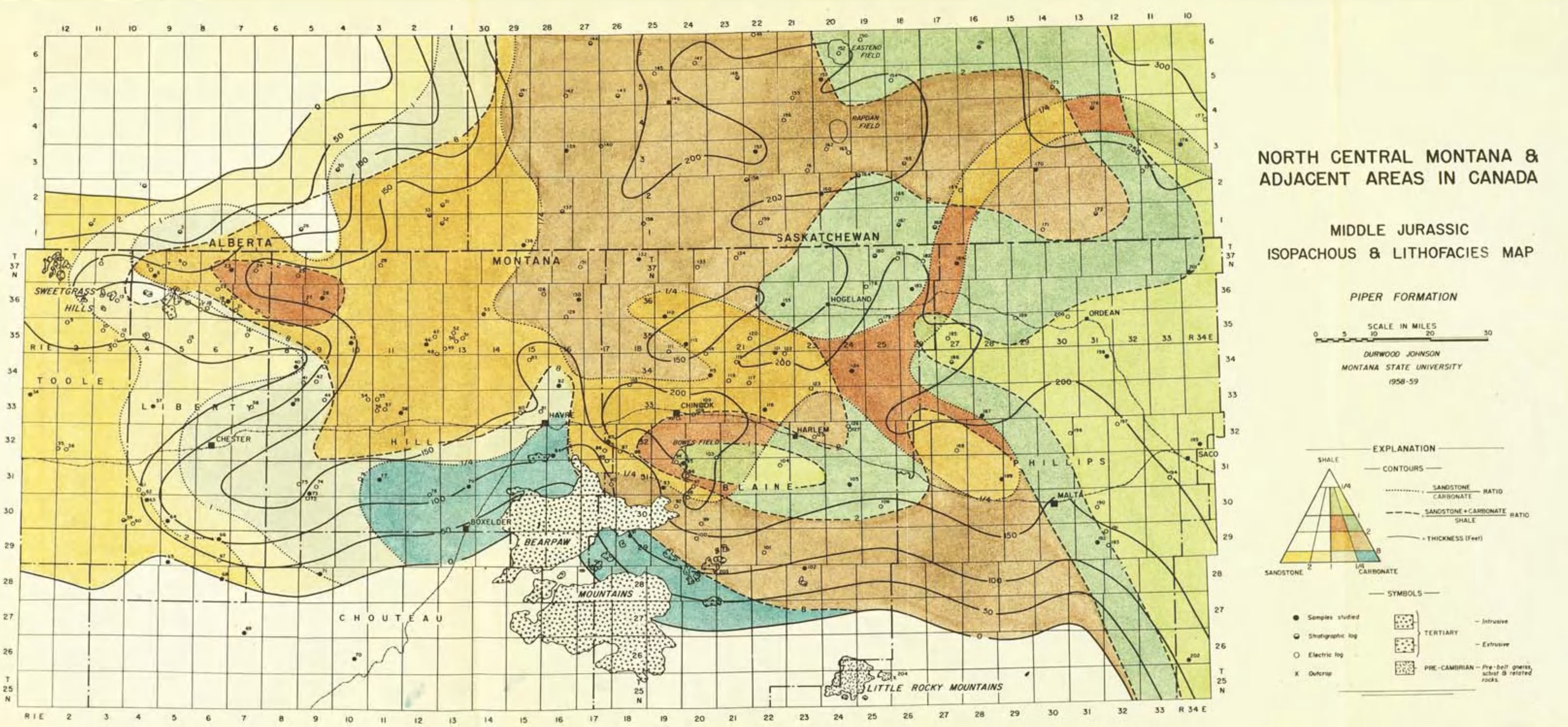
MIDDLE JURASSIC ISOPACHOUS & LITHOFACIES MAP

NESSON FORMATION

SCALE IN MILES

DURWOOD JOHNSON
MONTANA STATE UNIVERSITY
1958-59





NORTH CENTRAL MONTANA & ADJACENT AREAS IN CANADA
MIDDLE JURASSIC
ISOPACHOUS & LITHOFACIES MAP
PIPER FORMATION
SCALE IN MILES
0 5 10 20 30
DURWOOD JOHNSON
MONTANA STATE UNIVERSITY
1958-59
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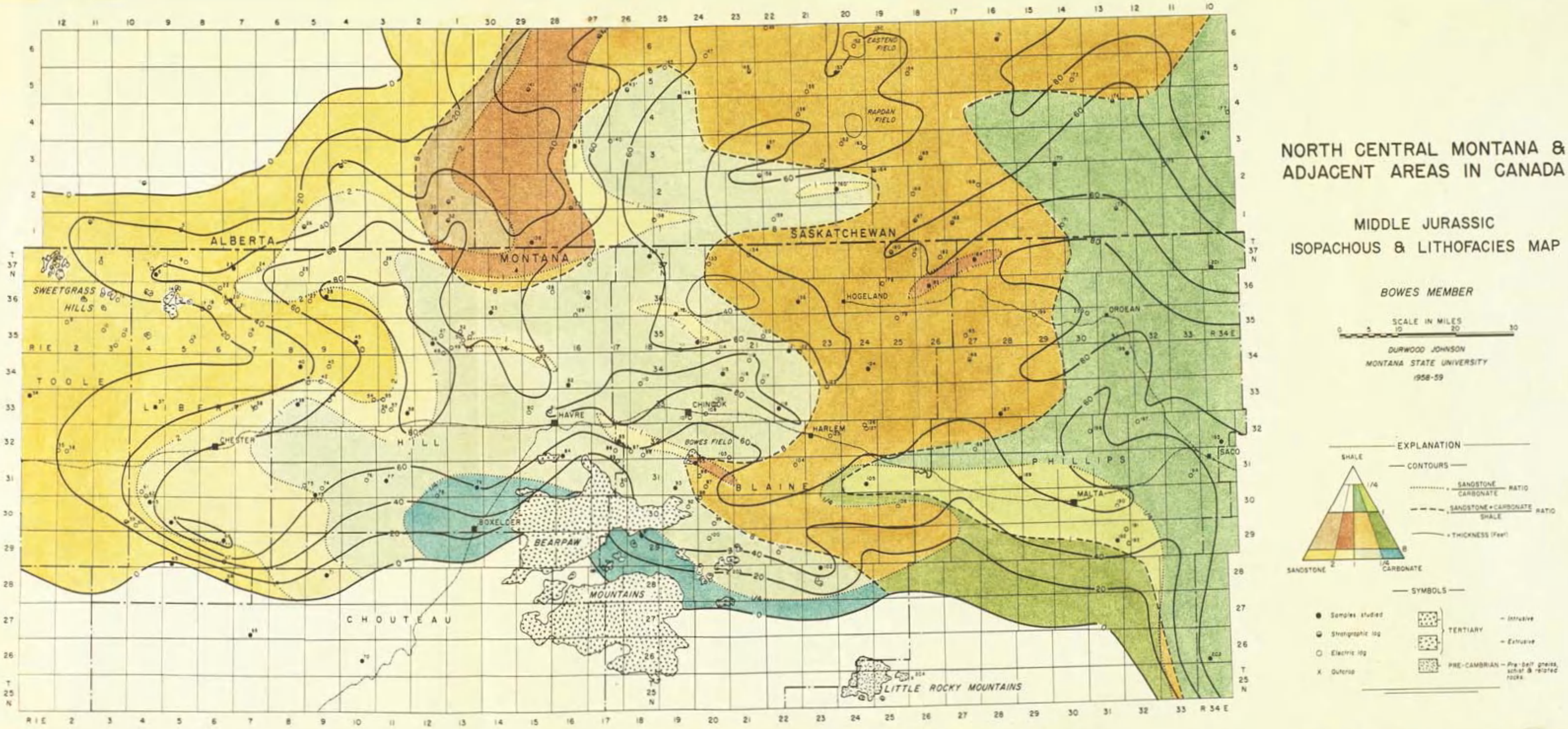
SYMBOLS
Samples studied
Stratigraphic log
Electric log
Outcrop
TERTIARY
Intrusive
Extrusive
PRE-CAMBRIAN
Pre-belt gneiss, schist & related rocks.
ALBERTA
SASKATCHEWAN
MONTANA
SWEETGRASS HILLS
TOOLE
LIBERTY
CHESTER
HILL
HAVRE
BOXELDER
BEARPAW MOUNTAINS
CHOUTEAU
CHINOOK
HARLEM
BOWES FIELD
BLAINE
HOGELAND
ORDEAN
PHILLIPS
MALTA
SACO
LITTLE ROCKY MOUNTAINS
EASTEND FIELD
RAPDAN FIELD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BOWES MEMBER
SCALE IN MILES
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CHOUTEAU
BLAINE
PHILLIPS
CHESTER
HAVRE
CHINOOK
HARLEM
HOGELAND
MALTA
SACO
ORDEAN
BOXELDER
BOWES FIELD
EASTEND FIELD
RAPDAN FIELD
BEARPAW MOUNTAINS
LITTLE ROCKY MOUNTAINS

LITHOLOGIC CONSTITUENTS AND THEIR DEPOSITIONAL ENVIRONMENTS

Sandstone

The quartz sand grains are primarily clear, well-sorted, fine-grained, and subrounded to subangular. Some of the sand grains exhibit a frosted appearance probably due to carbonate corrosion as percussion marks were noted sparingly during sample examination. Crystal facets or overgrowths are responsible for an angular appearance exhibited by some of the quartz grains and will be further discussed under cementation. The general subangularity of the quartz grains suggests an immature or youthful classification. Local uplift in western Montana during Bathonian supplied the sands.

The sands thin eastward from maximum accumulations in southern Liberty and northwestern Hill Counties with local isolated accumulations in the eastern sector of study (see Map 4). They are commonly interbedded with bioclastic limestone and grade laterally to sandy bioclastic limestone. Both the sands and associated bioclastic limestone are cross-bedded, suggesting strong depositional currents.

Prevailing winds and the profile of the coast and sea floor probably influenced the currents transporting sand and thereby localized sand accumulations.

Limestone

Limestone is a dominant lithologic constituent of both the Nesson and Piper formations. Thin sections indicate that the Middle Jurassic limestones include chemical, biochemical and bioclastic types (Pettijohn, 1957, Ch. 9). A biochemical origin is suggested for much of the limestone in the Nesson and Piper formations. A large percentage of the biochemical limestone may be classified as a calcarenite. Thin beds of fragmental limestone occur in both the Nesson and Piper formations.

A direct chemical origin is suggested for the dark-brown, non-fossiliferous, sublithographic limestone at the base of the Firemoon member. Oolites in the Bowes and upper part of the Firemoon members exhibit radial and/or concentric structure which suggests growth along the crystallographic axis implying chemical precipitation of calcium carbonate. According to Eardley (1938, p. 1372) agitation in warm waters is primarily responsible for their development. The oolites are usually well sorted and are occasionally cross-bedded.

Biochemical pisolites and chemical superficial oolites are common in the Bowes member. Some of the pisolites ($<$ 2 mm) are considered algal accretions. Superficial oolites usually contain calcareous pellets surrounded by a relatively thin layer of calcite. Calcareous pellets are generally uniform in size ($<$ .1 mm) and

Plate A

A-1. Bowes member of the Piper formation, Murphy Corporation No. 1-B Government (sec. 14, T. 37 N., R. 25 E.), Blaine County, Depth 4500-1 feet, X-nicols, X20.

Sandstone, calcareous, quartz grains fine to medium-grained, subrounded to subangular, facets developed.

A-2. Bowes member of the Piper formation, Murphy Corporation No. 1-B Government (sec. 14, T. 37 N., R. 25 E.), Blaine County, Depth 4521-22 feet, plane light, X20.

Sandy oolitic limestone, quartz grains coarse to fine-grained, subrounded to subangular, some exhibit facets, calcareous oolites, superficial oolites and pellets, fossil debris, some sparry calcite.

A-3. Bowes member of the Piper formation, Murphy Corporation No. 1-B Government (sec. 14, T. 37 N., R. 25 E.), Blaine County, Depth 4538-39 feet, plane light, X20.

Sandy limestone, quartz grains medium-grained, angular to subrounded, clastic limestone fragments partly dolomitized, some algal material present, voids may be result of carbonate leaching.

A-4. Bowes member of the Piper formation, Murphy Corporation No. 1-B Government (sec. 14, T. 37 N., R. 25 E.), Blaine County, Depth 4511-12 feet, plane light, X20.

Sandy limestone, sand grains fine to medium-grained, subangular to subrounded, well developed facets, quartz grains outline limestone interclasts.*

A-5. Bowes member of the Piper formation, Murphy Corporation No. 1-B Government (sec. 14, T. 37 N., R. 25 E.), Blaine County, Depth 4532-33 feet, plane light, X20.

Sandy bioclastic limestone, fossil debris and algal material, polysynthetic twinning passing through both sparry calcite and bioclastic fragments.

A-6. Bowes member of the Piper formation, Murphy Corporation No. 1-B Government (sec. 14, T. 37 N., R. 25 E.), Blaine County, Depth 4530-31 feet, plane light X20.

Limestone with silt streaks suggesting bedding planes.

*Interclast is used as defined by Folk (1959, P. 5) to classify previously consolidated sediments which have been reworked.

Figure A-1

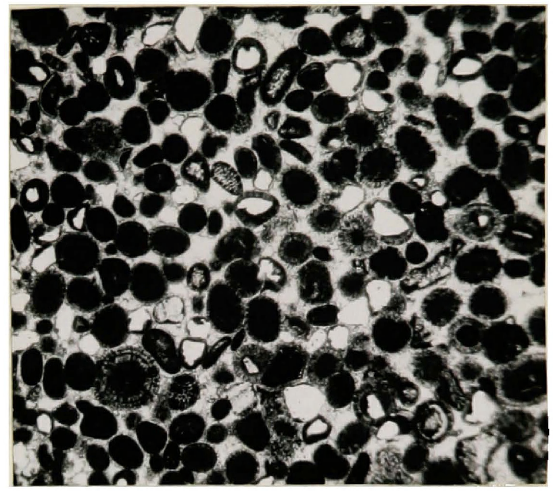

Figure A-2

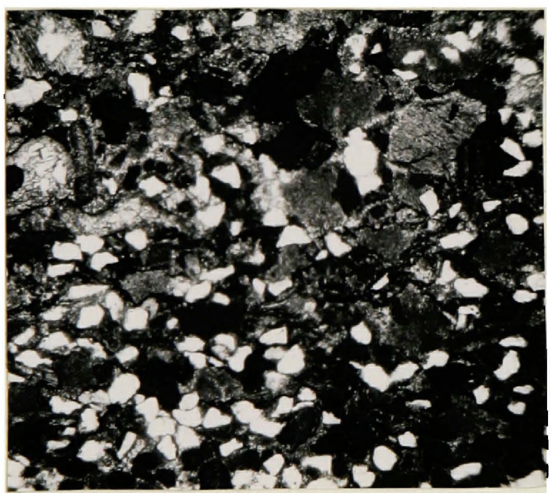

Figure A-3

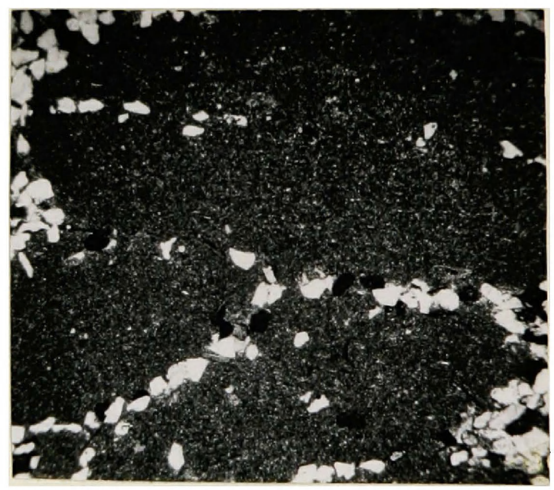

Figure A-4

Figure A-5

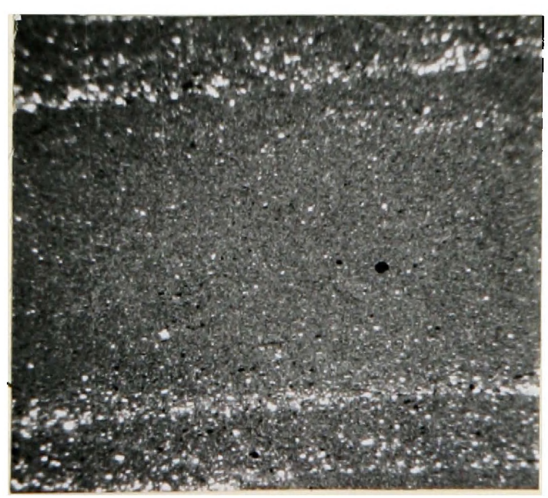

Figure A-6

have a rounded or spherical shape developed during transportation. They are distinguished from oolites by the lack of internal, radial and concentric structure.

The physical-chemical conditions which aid precipitation of calcium carbonate (Revelle and Fairbridge, 1957, p. 256) are shallow warm waters and a high concentration of calcium and/or carbonate ions. The important factors stimulating carbonate precipitation are increased water temperature, evaporation, supersaturated water in the presence of catalysts, photosynthesis and bacterial production of ammonia.

The presence of pelecypods, crinoids, brachiopods, ostracods, Foraminifera and algal remains support a biochemical and bioclastic classification for much of the limestone in the Nesson and Piper formations. The microcrystalline and cryptocrystalline texture is primarily due to recrystallization. The Firemoon limestone is believed to be primarily microstystalline ooze biochemically formed and recrystallized during diagenesis The bioclastic limestone of the Bowes member is predominantly composed of algal material and crinoid and pelecypod fragments.

Dolomite

Middle Jurassic dolomite is essentially limited to the Kline member of the Nesson formation with minor amounts in the Firemoon and Bowes members of the Piper formation. Thin beds of dark brown, dense dolomite and interbedded anhydrite in the Poe member of the Nesson formation may be the result of direct precipitation. However, most of the dolomite is considered a metasomatic replacement of Ca ions by Mg ions in limestone. This process may begin during sedimentation, but probably is initiated shortly after deposition during the early diagenetic stage (Fairbridge, 1957, p. 168).

The increased supplies of Mg ions needed for this conversion may in part be related to plant and animal life on or near the shelf area. Coralline algae (Clark and Wheeler, 1922, p. 9-13) have a high magnesium content. Chave (1954, p. 266-283) noted that the amount of magnesium manufactured by organisms is directly related in some species to an increase in water temperatures.

The observation by Weeks (1957, p. 55) that dolomitization is prominent among shelf or platform sediments implies that the complex physical, chemical and biochemical conditions needed to produce dolomite are most apt to occur in warm, shallow, nearshore waters with high salinity and alkalinity.

Gypsum and Anhydrite

Anhydrite is present in the Nesson formation and locally in the Piper formation in the area under investigation. It is beyond the scope of the present study to enter the controversy over primary versus secondary origin of anhydrite. It should be noted, however, that the latter theory is gaining support and may in part explain some of the massive anhydrite sections observed in the study area. The high sulfate content (Johnson, 1958, p. 81) in the interstitial water at Bowes field suggests the possibility of secondary anhydrite development.

Siltstone and Shale

The siltstones and shales in the Nesson and Piper formations are usually slightly calcareous and range in color from light gray to gray and gray-green. Belt Island is considered an important source of these sediments. Spheroidal pellets resembling clay galls (Sanderson, 1931) and smooth shelled ostracods in the Tampico shale member imply very limited wave activity. The shale suggests deposition in quiet waters (low kinetic energy) with normal circulation and in this case indicates a low stable adjoining land mass.

Red Beds

Middle Jurassic red beds are primarily confined to the Poe and Picard members of the Nesson formation and the Tampico and Bowes members of the Piper formation in the eastern sector of study. They are considered essentially of marine origin, a view originally adopted by Branson (1915), (1927) for a large part of the Mesozoic red beds in the Rocky Mountain region. Alternating marine and subareal conditions explain the majority of red coloration. The large areal extent, uniform sorting, bedding and thickness and association with anhydrite are cited as evidence. Generally the red beds are associated with marginal marine deposits and the grays with normal marine interior basinal sediments.

Miller and Folk (1955, p. 344) believe the dominane prerequisite for red beds is a primary igneous or metamorphic source area rich in iron-bearing minerals. Thus Middle Jurassic red bed coloration can be explained by the reprecipitation of hematite from magnetite and other iron minerals previously reduced by oxidation. However, some of the red coloration may be attributed to pre-existing red beds. Today it is evident red beds can form under a variety of environments and their coloration implies the presence of oxidizing conditions during or shortly after deposition.

Cementation

Calcium carbonate and silica are the principal cementing materials. The association of marine waters and oolite development suggests that the fluids trapped during deposition were alkaline, a condition favoring relatively high concentrations of both silica and calcium ions. Dapples (1959, p. 10) illustrates how high concentrations of both silica and calcium carbonate can coexist without affecting the individual solubility of one another. Emery and Rittenburg (1952, p. 795) note that the ratio of silica in solution is quite variable in regard to pH. Optimum conditions for precipitation of calcium and silica ions differ considerably. Silica precipitation is aided by low temperature and low pH as compared to calcium carbonate precipitation which is aided by high temperature and high pH. The solubility of both calcium carbonate and silica increases when subjected to pressure.

Initial development of the quartz overgrowths probably began shortly after deposition. Local temperature fluctuations and a high organic content could lower the pH of the interstitial fluids thereby aiding silica precipitation. The widespread development of quartz overgrowth is explained by later percolation of fresh water. Its low pH would aid precipitation of silica and increase the solubility of calcium carbonate causing it to dissolve. Oolite and fossil voids are occasionally present in thin sections suggesting calcium carbonate leaching.

Thin sections of the Bowes sandstone and limestone facies suggest that much of the carbonate matrix is recrystallized fossil debris (coralline algae, crinoids and pelecypods). The original structure of the oolites and fossil debris is modified by recrystallization. Structural alterations range from complete destruction to those exhibiting little or no change (see Plate A-2).

Secondary calcite cement (sparry calcite) is estimated to be approximately 10 per cent. Polysynthetic twinning passes through the sparry calcite in some cases (see Plate A-5) and is restricted to the recrystallized fragments in others, indicating development of secondary calcite both before and after recrystallization.

Replacement of quartz by calcite is illustrated in a majority of the thin sections. This is attributed to an increase in temperature having a greater effect on the solubility of calcium carbonate than the increased pressure of the overlying sediments.

ECONOMIC GEOLOGY

The Piper formation produces petroleum and/or gas in fields of the study area as shown in figure 4.

The Utopia field (T. 33 N., R. 4 E.) produces gas and minor amounts of petroleum. The five gas and three oil wells which comprise this field are currently shut in. Both structural and stratigraphic conditions control accumulation with the former more important. The major producing zone is a lenticular sandstone in the Bowes member (Rhodes, 1958, p. 223).

The Whitlash and Flat Coulee fields (Sweetgrass Hills vicinity) produce gas and minor amounts of petroleum. The Keith and Bears Den fields are capable of limited oil and gas production but are presently shut in. Most of these fields have multiple producing horizons with production in the Upper Jurassic and Lower Cretaceous sediments. Gas and petroleum accumulations appear to be structurally controlled. Porosity variations are important in some localities, especially in the Upper Jurassic and Lower Cretaceous sediments.

The Rudyard gas field (T. 33-34 N., R. 9 E.) is composed of three shut in gas wells. Hydrocarbon accumulation in the Bowes member appears to be both stratigraphically and structurally controlled. The field limits are as yet not defined.

The Bowes field is approximately 15 miles south of Chinook, Montana, on the northeast flank of the Bearpaw Mountains. In 1924 gas was discovered in the Eagle sandstone on the western side of this structure. Middle Jurassic oil was discovered in 1949 in the Northern Ordnance Guertzgen No. 1 well, which produced nearly 200 BOPD of asphaltic 20 A. P. I. gravity crude.

Production is primarily from beds of sandy, bioclastic limestone and calcareous sandstone in the lower part of the Bowes member of the Piper formation. The porosity (Johnson, 1958, p. 81) varies between 1.7 and 25 per cent, averaging about 12 per cent, with the permeability varying between 0.1 and 264 millidarcies. The upper 30 feet of the Firemoon limestone member produces in some wells.

Rapid facies changes of the Bowes member in short distances is illustrated by Hunt (1956, p. 188). His study of Bowes field indicates that all variations between sandstone and limestone are present with the upper part of the Bowes member grading laterally to shale in the southern part of the field.

In the area under investigation, production in southern Saskatchewan is limited to Rapdan and Eastend fields. However, immediately to the north are the Dollard, Instow, Bone Creek, Leon Lake, Gull Lake and North Premier fields. Production in Saskatchewan has a north-south alinement commonly termed the Dollard trend. Lenticular sands and bioclastic fragmental sandy limestone accumulations in the Bowes member (equivalent to the upper Shaunavon formation) are the petroleum reservoirs. Cumming (1958, p. 58) believes migration and accumulation are primarily controlled by permeability in the Dollard field. The sedimentation pattern observed by Cumming is very similar to that in the Bowes field.

Middle Jurassic sediments in north-central Montana contain both petroleum source and reservoir rocks. Petroleum accumulations are associated with small structural trends, porosity and permeability pinch-outs and unconformities. Numerous oil shows in the western sector of study have stimulated drilling activity though results to date are discouraging.

Fresh water recovered during drill stem tests and tar-like residues often found in cored intervals indicate a partial flushing of petroleum may have occurred in this study area except when prevented by structural and stratigraphic traps with suitable closure as in the case of Bowes field.

Any petroleum reservoirs discovered in the future in the area will be primarily stratigraphic accumulations as the sizeable structures have been drilled. Reevaluation of factors such as porosity and permeability trends, sedimentation patterns and hydrology will be needed for successful petroleum exploration in the future.

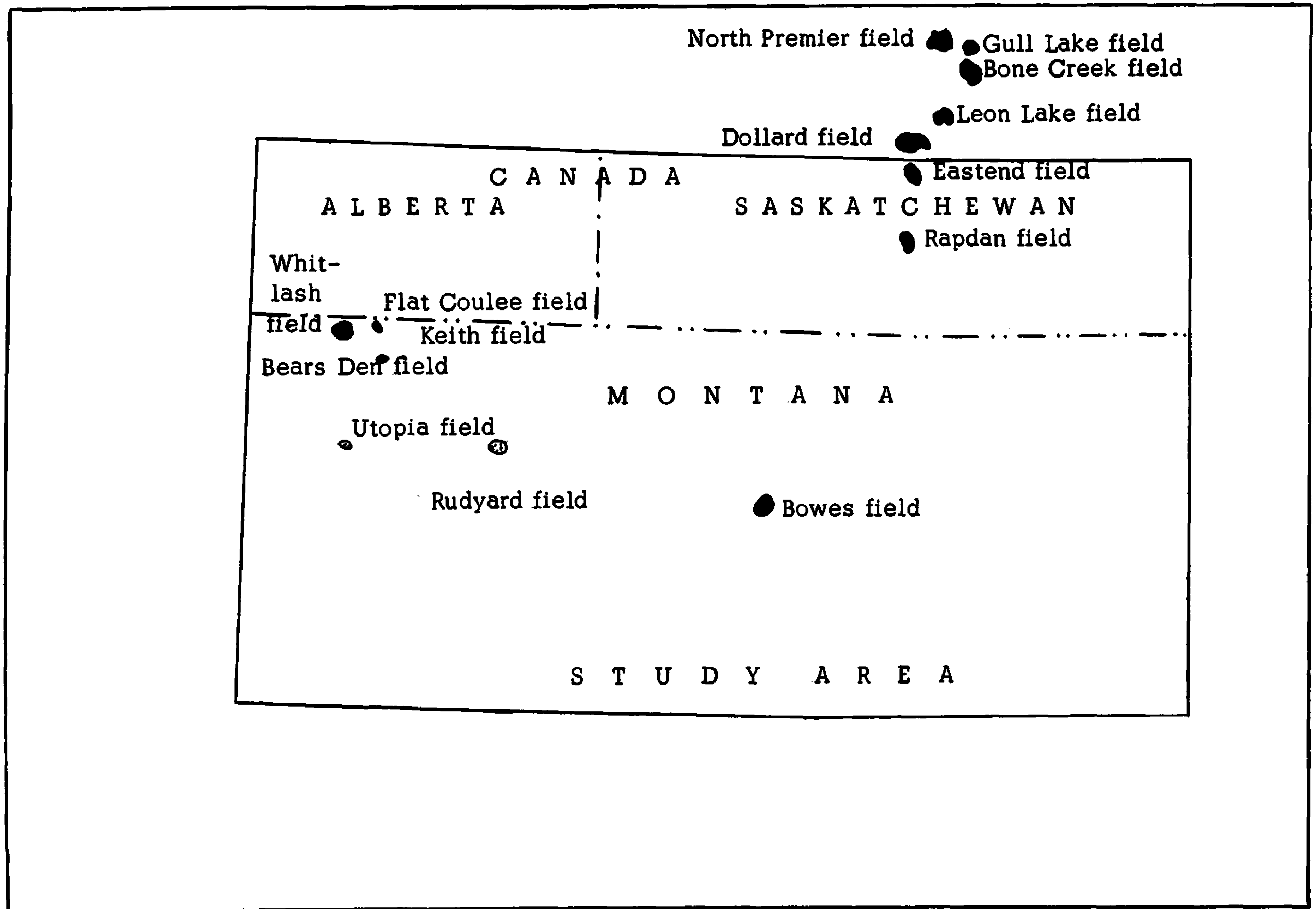

Figure 4. Index map illustrating fields producing oil and gas from Middle Jurassic horizons

SUMMARY

The purpose of this study was to add information on the Middle Jurassic sediments and their petroleum possibilities in north-central Montana and adjacent parts of Canada. The sediments were deposited on a shelf between the Williston Basin to the east and the Alberta shelf on the west and are included in the Nesson and Piper formations.

The Nesson formation is subdivided into three lithologic members which from bottom to top are: (1) Poe evaporite member, (2) Picard shale member, and (3) Kline carbonate member. The formation is approximately 150 feet thick in the northeastern portion of the study area, thinning southwest and pinching out near Belt Island and the Alberta shelf. Fossils and stratigraphic position indicate a Bathonian age.

The Piper formation also consists of three lithologic members which from bottom to top are: (1) Tampico shale member, (2) Firemoon limestone member, and (3) Bowes sandstone and shale member. The formation is about 300 feet thick in the eastern sector of the study, thinning to the west until it pinches out in the vicinity of Kevin-Sunburst Dome and the northern flank of Belt Island. Fossils and stratigraphic position of the formation indicate a Bathonian and Lower Callovian age.

Middle Jurassic sedimentation indicates a regular deposition pattern modified by local environmental conditions. The normal shelf to basin sequence of sandstone, limestone and shale suggests that the pinchout edge is primarily a result of non-deposition. The sediments also indicate deposition in warm shallow, well-aereated waters. Sea level fluctuations, local topographic irregularities and minor warping periodically hindered normal marine circulation and resulted in anhydrite and red bed deposits. However, the high sulfate content of subsurface water in the area suggests that some of the massive anhydrite sections may be, at least in part, the result of secondary replacement.

Middle Jurassic sandstone is confined primarily to the Bowes member of the Piper formation. The sandstone thins eastward from maximum accumulations in southern Liberty and northern Hill Counties and is commonly interbedded with bioclastic limestone. Calcium carbonate and silica are the principal cementing materials.

Limestones are of chemical, biochemical and bioclastic types. Abundant fossil remains support a biochemical and bioclastic classification for much of the Middle Jurassic limestone.

The sediments contain both petroleum source and reservoir rocks. Petroleum accumulations are associated with small structural trends, porosity and permeability pinchouts and unconformities.

Production is primarily from beds of sandy, bioclastic limestone and calcareous sandstone in the lower part of the Bowes member of the Piper formation. Numerous oil shows in the western sector of the study have stimulated recent drilling activity; however, results to date have not been very encouraging.

Petroleum reservoirs discovered in the future in the area will be primarily stratigraphic accumulations as the major structures have been drilled. Reevaluation of factors such as porosity and permeability trends, sedimentation patterns and hydrology will be needed for successful future exploration. It is hoped that the material in this study report may be helpful in this reevaluation.

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APPENDIX

SURFACE AND SUBSURFACE CONTROL

1. Gas Exploration Company of Alberta Ltd., No. 2 Penhorn, L.S.D. 14, Sec. 25, T. 2, R. 10, W. 4th Mer.

2. Jet Oils Ltd., Ashmont Jet, No. 1 Knappen, L.S.D. 6, Sec. 28, T. 1, R. 11, W. 4th Mer.

3. Gas Exploration Company of Alberta Ltd., No. 1 Penhorn, L.S.D. 7, Sec. 24, T. 1, R. 9, W. 4th Mer.

4. Texas Company, No. 1 A. Fey, C SW SE Sec. 18, T. 37 N., R. 3 E.

5. Union Oil of California No. 1 Mahoney, SW NE Sec. 22, T. 37 N., R. 4 E.

6. Western Natural Gas, No. 4 Hicks, C NE NW Sec. 26, T. 37 N., R. 4 E.

7. Montana Dakota, No. 606 Bingham, C SE SE Sec. 13, T. 37 N., R. 4 E.

8. Phillips Petroleum, No. 1 Millen, NW NE NW Sec. 15, T. 37 N., R. 5 E.

9. Texas Company, No. 1 Black Gold, C NE SW Sec. 5, T. 35 N., R. 2 E.

10. Texas Company, No. 1 Gov't., C NE NW Sec. 17, T. 35 N., R. 3 E.

11. Anschutz Drilling Company, No. 2 Henry, C NE SW Sec. 27, T. 35 N., R. 3 E.

12. Anschutz Drilling Company, No. 1 Henry, C SE SE Sec. 14, T. 35 N., R. 3 E.

13. Anschutz Drilling Company, No. 1 Morris, C SE SE Sec. 15, T. 36 N., R. 3 E.

14. Sanderson, O. E., Sec. 8, T. 36 N., R. 5 E. (Measured surface section.)

15. Montana Dakota Utilities No. 605, C E SW Sec. 23, T. 35 N., R. 5 E.

16. Union Oil of California, No. 22 State, C Sec. 16, T. 35 N., R. 7 E.

17. Montana Dakota, No. 602 Frazer, SE SW NW Sec. 30, T. 36 N., R. 6 E.

18. Texas Company, No. 1 Sorrell Gov't., C NE NW Sec. 29, T. 36 N., R. 6 E.

19. Texas Company, No. 1 Osler, C NW NW Sec. 23, T. 36 N., R. 6 E.

20. Texas Company, No. 1 Colbry, C SW SW Sec. 13, T. 36 N., R. 6 E.

21. Carter Oil Company, No. 1 Tempel, C SE SW Sec. 30, T. 36 N., R. 6 E.

22. Anaconda Copper, No. 1 Gunderson, NE SW SW Sec. 3, T. 36 N., R. 6 E.

23. Texas Company, No. 1 Northern Farms, C NE NW Sec. 24, T. 37 N., R. 6 E.

24. S. G. S. Oil and Gas, No. 1 Smith, NE NW Sec. 22, T. 37 N., R. 7 E.

25. H. D. Hadley-Kulberg Drilling, No. 1 Williamson, C NW NE Sec. 26, T. 37 N., R. 8 E.

26. Calvan Consolidated Oil and Gas Corporation Ltd., No. 1 Calvan Tartan Sapphire, L. S. D. 16, Sec. 20, T. 1, R. 5, W. 4th Mer.

27. H. D. Hadley, Kulberg Drilling, No. 1 Austin, C SE Sec. 18, T. 36 N., R. 9 E.

28. DeKalb, No. 1 Kaercher, C NW Sec. 15, T. 36 N., R. 9 E.

29. DeKalb, No. 1 Neuworth, C SE NE Sec. 18, T. 37 N., R. 11 E.

30. Dome Exploration, No. 12-9 Dome Supertest Et Al Bain, L. S. D. 12, Sec. 9, T. 3, R. 4, W. 4th Mer.

31. Socony, No. 1 Wildhorse, L. S. D. 15, Sec. 36, T. 2, R. 1, W. 4th Mer.

32. British American Company Ltd., No. 10-29 Sage Creek, L. S. D. 10, Sec. 29, T. 1, R. 1, W. 4th Mer.

33. British American Company Ltd., No. 10-8 Sage Creek, L. S. D. 10, Sec. 8, T. 2, R. 1, W. 4th Mer.

34. Anschutz Drilling, No. 1 Gibson, NW NE NW Sec. 8, T. 33 N., R. 1 E.

35. Northern Ordnance, No. 1 Prodger, C SE SE Sec. 29, T. 32 N., R. 2 E.

36. Northern Ordnance, No. D-1 Tool State, C NW NW Sec. 30, T. 32 N., R. 2 E.

37. Texas Company, No. 2 Nick Lass, NW NE SW Sec. 14, T. 33 N., R. 4 E.

38. Texas Company, No. M-2071 Joplin State, C SE SE Sec. 16, T. 33 N., R. 7 E.

39. DeKalb, No. 1 Haaland, C NW NW Sec. 14, T. 33 N., R. 8 E.

40. El Paso Natural Gas, No. 1 Haaland, C SE Sec. 11, T. 34 N., R. 8 E.

41. El Paso Natural Gas, No. 1 Ditmar, C SE NW Sec. 30, T. 34 N., R. 9 E.

42. El Paso Natural Gas, No. 1 Anderson, C NE Sec. 28, T. 34 N., R. 9 E.

43. Texas Company, No. 1-C Bradbury, C NE NE Sec. 10, T. 33 N., R. 7 E.

44. El Paso Natural Gas, No. 1 Huntley, C SE Sec. 10, T. 34 N., R. 9 E.

45. Seaboard Union, No. 1 Dolezal NE SW SW Sec. 21, T. 35 N., R. 10 E.

46. DeKalb, No. 1-A Gov't., C SW SW Sec. 22, T. 35 N., R. 12 E.

47. Champlin Oil and Refining, No. 1 Gov't. C SW SE Sec. 14, T. 35 N., R. 12 E.

48. DeKalb, No. 43-35 Gov't., C NE SE Sec. 35, T. 35 N., R. 12 E.

49. DeKalb, No. 1 Staples, C SE SW Sec. 30, T. 35 N., R. 13 E.

50. DeKalb, No. 2 Meland, C NW NW Sec. 22, T. 35 N., R. 13 E.

51. DeKalb, No. 1 Meland, C NW SW Sec. 21, T. 35 N., R. 13 E.

52. DeKalb, No. 1 Larson, C NE NE Sec. 17, T. 35 N., R. 13 E.

53. Texas Company, No. 1 Verploegen, C NE NE Sec. 31, T. 36 N., R. 14 E.

54. Skelly Oil, No. 1 Breidal, C SE NW Sec. 12, T. 33 N., R. 10 E.

55. Empire State Oil, No. 1 Aronow NW NW NE Sec. 7, T. 33 N., R. 11 E.

56. Skelly Oil, No. 1 Rambo, C NE NE Sec. 19, T. 33 N., R. 11 E.

57. Northern Pump, No. 1 State, SW SW SW Sec. 16, T. 33 N., R. 11 E.

58. Sohio, No. 1 Murr C SE SE Sec. 23, T. 33 N., R. 11 E.

59. Amerada, No. 1 Kolestad, C NW NE Sec. 25, T. 30 N., R. 3 E.

60. Amerada, No. 1 Kinread, NW NW SW Sec. 29, T. 30 N., R. 4 E.

61. Amerada, No. 3 Kolestad, C NW NW Sec. 33, T. 31 N., R. 4 E.

62. Amerada, No. 2 Kolestad, C SE SE Sec. 33, T. 31 N., R. 4 E.

63. Amerada, No. 1 Kolestad Ranch, SW SW NW Sec. 3, T. 30 N., R. 4 E.

64. L. B. O'Neil, No. 1 Brown, NW SW NW Sec. 29, T. 30 N., R. 5 E.

65. Amerada, No. 1 Clara Jones, NW NW NW Sec. 32, T. 29 N., R. 5 E.

66. Amerada, No. 1 Paul, C SW NW Sec. 11, T. 29 N., R. 6 E.

67. Texas Company, No. M 15-72 State, NE SE SW Sec. 26, T. 29 N., R. 6 E.

68. Amerada, No. 1 Skierka, C SE SW SE Sec. 11, T. 28 N., R. 6 E.

69. Hodge and Association, No. 1 Bartlett NE NE Sec. 33, T. 27 N., R. 7 E.

70. DeKalb, No. 1 Lippart, NE SW SE Sec. 22, T. 26 N., R. 10 E.

71. Blubaugh, No. 1 Lorenzen, SE SE SE Sec. 3, T. 28 N., R. 9 E.

72. DeKalb, No. 1 LaBorta, C NW NW Sec. 5, T. 30 N., R. 9 E.

73. DeKalb, No. 1 Ludwig, C SW NE Sec. 32, T. 31 N., R. 9 E.

74. DeKalb, No. 1 Farrington, SW NE Sec. 28, T. 31 N., R. 9 E.

75. DeKalb, No. 1 Rathbun, C NE SE Sec. 24, T. 31 N., R. 8 E.

76. DeKalb, No. 1 Baranek-McNulty, C NE SW Sec. 14, T. 31 N., R. 10 E.

77. DeKalb, No. 1 Borlaug, C SW SE Sec. 17, T. 31 N., R. 11 E.

78. McAlester Fueld, No. 1-A Rambo, C SW SW Sec. 35, T. 31 N., R. 12 E.

79. Texas Company, No. 1 Kiemele, SE NW NE Sec. 26, T. 31 N., R. 13 E.

80. Texas Company, No. 1 K. H. Long, C SW SW Sec. 20, T. 33 N., R. 15 E.

81. British American, No. 1 Larson, NW SE Sec. 23, T. 33 N., R. 15 E.

82. Amerada, No. 1 State "C", C NE SE Sec. 4, T. 34 N., R. 15 E.

83. Amerada, No. 1 Montana State "D", C NW NE Sec. 32, T. 34 N., R. 16 E.

84. Northern Pump, No. 1 Blackstone, NE NE NE Sec. 32, T. 32 N., R. 16 E.

85. Northern Ordnance, No. 1 Morphey, C SE SE Sec. 14, T. 32 N., R. 17 E.

86. Northern Pump, No. 1 James Davey, SW SE NW Sec. 26, T. 32 N., R. 17 E.

87. True and Brown, No. 1 Moll, NE NE SW Sec. 20, T. 32 N., R. 18 E.

88. True and Brown, No. 1 Hiller, C NW NE Sec. 33, T. 32 N., R. 18 E.

89. Northern Pump, No. 1 O'Neil, NE NW NE Sec. 2, T. 31 N., R. 17 E.

90. Northern Pump, No. 1 Olson, NE NE NW Sec. 25, T. 31 N., R. 17 E.

91. Texas Company, No. 1 Davis Ranch, C SE SW Sec. 4, T. 29 N., R. 18 E.

92. Appell Drilling Co., No. 1 Kuhr, SE SE SW Sec. 11, T. 30 N., R. 19 E.

93. Montana Canadian, No. 1A Sprinkle, S SW SW Sec. 28, T. 31 N., R. 19 E.

94. Northern Ordnance, No. 1 Guertzgen, SW NW NE Sec. 2, T. 31 N., R. 19 E.

95. Northern Ordnance, No. 5 Guertzgen, NE SW SE Sec. 1, T. 31 N., R. 19 E.

96. Tschern, No. 1 Rasmusson, C NW SW Sec. 18, T. 31 N., R. 20 E.

97. Renwar Oil Corp., No. 1 Sprinkle, C SW NW Sec. 29, T. 31 N., R. 20 E.

98. British American, No. 1 Sprinkle, C NW SE Sec. 6, T. 30 N., R. 20 E.

99. Wyoton Oil and Gas, No. 1 Miller, SE NW SE Sec. 28, T. 30 N., R. 20 E.

100. Pan American, No. 1 Miller Brothers Inc., C SE NE Sec. 8, T. 29 N., R. 20 E.

101. Fred R. Munger, No. 1 Siert, C S SE SW Sec. 20, T. 29 N., R. 22 E.

102. Phillips Petroleum, No. 1 Fort Belknap A, SW NW Sec. 3, T. 28 N., R. 23 E.

103. Kirby Petroleum, No. 1 State, C SE SW Sec. 36, T. 32 N., R. 20 E.

104. Phillips Petroleum, No. 1 Gos, NW NW Sec. 11, T. 31 N., R. 22 E.

105. Phillips Petroleum, No. 1-A Savoy, C NW SW Sec. 26, T. 31 N., R. 24 E.

106. Mobil Producing, No. F-11-15-I, NE NW NW Sec. 15, T. 30 N., R. 25 E.

107. Chinook Project, Heyting et al, NE NE NE Sec. 34, T. 33 N., R. 19 E.

108. American Metals, No. 1 Taylor's Daughter, C NW SE Sec. 30, T. 33 N., R. 20 E.

109. American Metals, No. 1 State, C SW SW Sec. 16, T. 33 N., R. 20 E.

110. B. and R. Oil Company, No. 1 Lohman, C NW NE Sec. 32, T. 34 N., R. 18 E.

111. Battle Creek Oil Co., No. 1 Holman-Montgomery, C SW SW Sec. 33, T. 35 N., R. 19 E.

112. Tidewater, No. 1 Unruh, NE NW SE Sec. 32, T. 36 N., R. 19 E.

113. Porter Oil, No. 1 Gov't., C SW NW Sec. 25, T. 35 N., R. 19 E.

114. Sohio, No. 1 Tilleman, C NE NE Sec. 4, T. 34 N., R. 20 E.

115. Sohio, No. 1-A Flynn, C SW SE Sec. 22, T. 34 N., R. 20 E.

116. DeKalb, No. 1 J. A. Graber, SW SE Sec. 30, T. 34 N., R. 21 E.

117. Lininger, No. 1 Jacobson, C NW NW Sec. 35, T. 34 N., R. 21 E.

118. Amerada, No. 1 Miller, C NE SE Sec. 19, T. 33 N., R. 22 E.

119. Texas Company, No. 1 Gov't., C NE SE Sec. 8, T. 34 N., R. 21 E.

120. Montex Oil and Gas Co., No. 1 Miller Brothers, C SW SW Sec. 23, T. 35 N., R. 21 E.

121. Amerada, No. 1 Reed, C NW NE Sec. 4, T. 34 N., R. 22 E.

122. C. L. Thompson, No. 1 Nickerson, C SW NW Sec. 2, T. 34 N., R. 22 E.

123. Amerada, No. 1 Anderson, C NW NE Sec. 4, T. 33 N., R. 23 E.

124. Amerada, No. 1 Modic, SE SE NE Sec. 22, T. 34 N., R. 24 E.

125. DeKalb, No. 1 Gov't., C NW NW Sec. 14, T. 32 N., R. 23 E.

126. Fair-Woodward, No. 1 Miller, C NE SE Sec. 3, T. 32 N., R. 24 E.

127. Nickerson and Nickerson, No. 1 H. Miller, C NW NW Sec. 11, T. 32 N., R. 24 E.

128. General Petroleum Corp., No. 36-12P Erickson, SW NE SW Sec. 12, T. 36 N., R. 15 E.

129. Pathfinder Petroleum Ltd., No. 1 Hansen, C SE SE Sec. 33, T. 36 N., R. 16 E.

130. Amerada, No. 1 Lenhart, C SW SW Sec. 13, T. 36 N., R. 16 E.

131. Amerada, No. 1 H. H. Wade, C NE NE Sec. 23, T. 37 N., R. 16 E.

132. Texas Company, No. 1 G. A. Miller, NW SE SE Sec. 9, T. 37 N., R. 18 E.

133. Murphy Corporation, No. 1-A Gov't., C NW NE Sec. 19, T. 37 N., R. 20 E.

134. Tidewater Association, No. 1 Munson-Torvick, C SW SW Sec. 8, T. 37 N., R. 21 E.

135. Amerada, No. 1 Bergum, C SE SW Sec. 23, T. 36 N., R. 22 E.

136. Shell-Canada Southern, No. 2 Governlock, L.S.D. 16, Sec. 3, T. 1, R. 29, W. 3rd Mer.

137. Shell, No. 10 Barclay Supreme, L.S.D. 7, Sec. 2, T. 2, R. 28, W. 3rd Mer.

138. Shell-Albercan, No. A 6-30 Arena, L.S.D. 6, Sec. 30, T. 1, R. 25, W. 3rd Mer.

139. Texas, No. A-6-30 Consul, L.S.D. 6, Sec. 30, T. 3, R. 27, W. 3rd Mer.

140. Imperial Oil, No. 4-31 Battle Creek, L.S.D. 4, Sec. 31, T. 3, R. 26, W. 3rd Mer.

141. Texaco, No. A-14-11 Battle Creek, L.S.D. 14, Sec. 11, T. 5, R. 29, W. 3rd Mer.

142. Imperial et al, No. 14-7 Senate, L.S.D. 14, Sec. 7, T. 5, R. 27, W. 3rd Mer.

143. British American, No. 12-10 Cypress Lake, L.S.D. 12, Sec. 10, T. 5, R. 26, W. 3rd Mer.

144. British American Co-op., No. 2-26 Culvan Cypress Lake, L.S.D. 2, Sec. 26, T. 6, R. 27, W. 3rd Mer.

145. British American, No. 12-34 Cypress Lake, L.S.D. 12, Sec. 34, T. 5, R. 25, W. 3rd Mer.

146. Imperial et al, No. 1-1 Robsart, L.S.D. 1, Sec. 1, T. 5, R. 25, W. 3rd Mer.

147. Socony Vacuum, No. 1 Palisade, L.S.D. 4, Sec. 11, T. 6, R. 24, W. 3rd Mer.

148. Socony Vacuum, No. 1 West Prairie Olga, L.S.D. 11, Sec. 25, T. 5, R. 23, W. 3rd Mer.

149. Mobil, No. 32-9 Woody Durrell, L.S.D. 9, Sec. 32, T. 6, R. 22, W. 3rd Mer.

150. Tidewater, No. 1 East Crown, L.S.D. 4, Sec. 28, T. 6, R. 19, W. 3rd Mer.

151. Socony-Vacuum-Sohio, No. 15-7 Beaver Valley, L.S.D. 7, Sec. 15, T. 6, R. 16, W. 3rd Mer.

152. Tidewater, No. 1 East Crown, L.S.D. 15, Sec. 11, T. 6, R. 20, W. 3rd Mer.

153. Tidewater, No. 15-20 White Mud Crown, L.S.D. 15, Sec. 20, T. 5, R. 20, W. 3rd Mer.

154. Imperial-Tidewater, No. 5-20 Chambery, L.S.D. 5, Sec. 20, T. 5, R. 18, W. 3rd Mer.

155. Socony Vacuum, No. 4-15 Woodley Southern North Eastbrook, L.S.D. 15, Sec. 4, T. 5, R. 21, W. 3rd Mer.

156. Socony Vacuum, No. 17-13 Southern Eastbrook, L.S.D. 13, Sec. 17, T. 4, R. 21, W. 3rd Mer.

157. Conso-Shell, Clayden No. 16-20, L.S.D. 16, Sec. 20, T. 3, R. 22, W. 3rd Mer.

158. Canada Southern Shell, No. 1-36 Staynor, L.S.D. 1, Sec. 36, T. 2, R. 23, W. 3rd Mer.

159. Tidewater, No. 1-29 Boundary Crown, L.S.D. 1, Sec. 29, T. 1, R. 22, W. 3rd Mer.

160. Tidewater, No. 1 Karluh Crown, L.S.D. 15, Sec. 18, T. 2, R. 20, W. 3rd Mer.

161. Tidewater, No. 1 Loomis Crown, L.S.D. 5, Sec. 1, T. 3, R. 21, W. 3rd Mer.

162. Tidewater, No. 1 Frontier Crown, L.S.D. 13, Sec. 21, T. 3, R. 20, W. 3rd Mer.

163. Tidewater, No. 4-19 East Frontier Crown, L.S.D. 4, Sec. 19, T. 3, R. 19, W. 3rd Mer.

164. Tidewater, No. 1 Maxum Crown, L.S.D. 15, Sec. 31, T. 2, R. 19, W. 3rd Mer.

165. Imperial Oil-Tidewater, No. 6-10 Climax, L.S.D. 6, Sec. 10, T. 3, R. 18, W. 3rd Mer.

166. Tidewater, No. 3 Climax, L.S.D. 9, Sec. 7, T. 2, R. 18, W. 3rd Mer.

167. Tidewater, No. 2 Imperial Climax, L.S.D. 6, Sec. 20, T. 1, R. 18, W. 3rd Mer.

168. Tidewater, No. 4 Climax, L.S.D. 14, Sec. 17, T. 1, R. 17, W. 3rd Mer.

169. Tidewater, No. 1 Conuck Crown, L.S.D. 16, Sec. 13, T. 2, R. 17, W. 3rd Mer.

170. Imperial, McCarty-Coleman, No. 15-31 Masefield, L.S.D. 15, Sec. 31, T. 2, R. 14, W. 3rd Mer.

171. Sohio, McCarty-Coleman, No. 1 Monchy, L.S.D. 13, Sec. 16, T. 1, R. 1, W. 3rd Mer.

172. Amerada-Shell, No. S-E 10-26 Crown, L.S.D. 10, Sec. 26, T. 1, R. 13, W. 3rd Mer.

173. Sohio, McCarty-Coleman, No. 1 Hillandale, L.S.D. 4, Sec. 11, T. 5, R. 14, W. 3rd Mer.

174. Imperial Oil, No. 16-23 Val Marie, L.S.D. 16, Sec. 23, T. 4, R. 13, W. 3rd Mer.

175. Amerada-Shell, No. 5-31 Crown "S-A", L.S.D. 5, Sec. 31, T. 2, R. 11, W. 3rd Mer.

176. Shell, No. 7 Wood-Mountain, L.S.D. 5, Sec. 20, T. 3, R. 10, W. 3rd Mer.

177. Amerada-Shell, No. S-K 16-12 Crown, L.S.D. 16, Sec. 12, T. 4, R. 10, W. 3rd Mer.

178. Amerada, No. 1 Warren, C NW NW Sec. 7, T. 36 N., R. 25 E.

179. Amerada, No. 1 Halverson, C NW SE Sec. 4, T. 35 N., R. 25 E.

180. Murphy Corporation, No. 1-B Gov't., C SE SE Sec. 7, T. 37 N., R. 25 E.

181. Murphy Corporation, No. 1-B Gov't., C NE NE Sec. 14, T. 37 N., R. 25 E.

182. Murphy Corporation, No. 1-A Gov't., C NW SW Sec. 15, T. 37 N., R. 26 E.

183. Amerada, No. 1 Gov't.-Wheaton, C SW NW Sec. 9, T. 36 N., R. 26 E.

184. Murphy Corporation, No. 1-A Gov't., C NE NE Sec. 21, T. 37 N., R. 27 E.

185. Murphy Corporation, No. 1-A Gov't., C SE SE Sec. 21, T. 35 N., R. 27 E.

186. Chief Exploration, No. 1 State, C NE NW Sec. 16, T. 34 N., R. 27 E.

187. DeKalb, No. 1 Williamson, C SW NW Sec. 32, T. 33 N., R. 28 E.

188. Carter Oil Co., No. 1 Solberg, C NW NW Sec. 35, T. 32 N., R. 27 E.

189. Carter Oil Co., No. 1 Tuma, C NW NE Sec. 25, T. 31 N., R. 28 E.

190. Flank Oil Company, No. 1 Gov't.-Barr, C SW NE Sec. 22, T. 30 N., R. 31 E.

191. DeKalb, No. 1 Gijersing, C SE NW Sec. 12, T. 29 N., R. 31 E.

192. DeKalb, No. 1 Henry, C SE NE Sec. 22, T. 29 N., R. 31 E.

193. DeKalb, No. 1 Ulrich, SW SE Sec. 24, T. 29 N., R. 31 E.

194. Shell, No. 13-26 Gov't., C NW SW Sec. 26, T. 31 N., R. 33 E.

195. Texas Company, No. 2 Bowdoin, C NW NE Sec. 34, T. 34 N., R. 34 E.

196. DeKalb, No. 13-43 Gov't., C NE SE Sec. 13, T. 32 N., R. 30 E.

197. Texas Company, No. 1-822 Bowdoin, C SW SW Sec. 8, T. 32 N., R. 32 E.

198. Texas Company, No. 1 Whitewater Unit, C SE SE Sec. 11, T. 34 N., R. 31 E.

199. DeKalb, No. 1 Flansaas, C SW SW Sec. 5, T. 35 N., R. 29 E.

200. Chicago Corporation, No. 1 Gov't.-Holly, NE NW SW Sec. 2, T. 35 N., R. 30 E.

201. Gulf Oil Corporation, No. 1 Gov't., SW SW SW Sec. 31, T. 37 N., R. 34 E.

202. California No. 1 Gov't., C NE NW Sec. 33, T. 26 N., R. 34 E.

203. Imlay, et al, 1948, Sec. 12, T. 28 N., R. 20 E. (Measured surface sections.)

204. Imlay, et al, 1948, Sec. 7, T. 25 N., R. 26 E. (Measured surface sections.)